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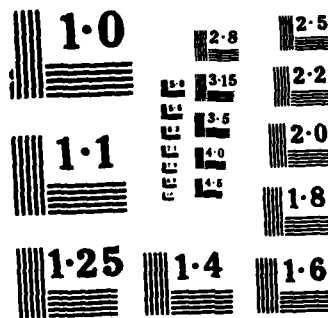
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The Pennsylvania State University  
The Graduate School  
Department of Civil Engineering

A Network Adjustment Technique for the Analysis of  
Schedule Delay and Acceleration Claims

A Report in  
Civil Engineering  
by

Scott Michael Merrill

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JAN 23 1986  
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Submitted in Partial Fulfillment  
of the Requirements  
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Master of Engineering

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## Chapter I

### INTRODUCTION

Contractors and owners generally agree that the handling of claims arising from delays to the schedule is a significant and growing problem. These claims are frequently difficult to negotiate. One large problem in resolving claims is the lack of documentation. An additional problem is the inability to determine the cause-effect relationship of delays.

Critical Path Method (CPM) schedules have proven to be useful in determining delay effects. Adjusting a CPM schedule to reflect critical delays is a viable method of settling delay claims. The procedure for adjusting a CPM network has never been documented in detail. This report will present a methodology for using CPM network schedules to determine the impact of project delays. An additional procedure for evaluating acceleration claims using network schedules will also be presented.

#### Background

There are few problems which have a more devastating effect upon a contractor and owner than construction delays. These can lead to extremely costly and complex claims and, ultimately, to litigation. Also, delays can deprive the owner of the timely use of the completed facility and force the contractor to incur increased costs. Both the

contractor and the owner are concerned that they may be held responsible and may be required to pay damages.

#### Significance of Delay Claims

The number of delay claims continues to rise in the competitive construction market. Contractors' bids contain small margins for absorbing costly delays. Jones [1] reviewed over 320 claims obtained from six State Departments of Transportation (DOTs) and found that two out of five claims had a schedule-related problem as a root cause. Additionally, the monetary value of claims involving delay was significantly higher than that of nondelay claims. "In all cases, the requested compensation for the delay claim was 152% to 775% higher monetarily than for the nondelay claim." [1]

The contractor's claim is often centered around delays outside his/her control that presumably resulted in the project finishing late. Valid resolution of a claim is dependent upon determining the cause-effect relationship of schedule delays.

#### Value of a CPM Schedule

An updated CPM schedule can be a very valuable tool both during and after the completion of the project. Few projects advance as planned in the original schedule. Some activities are delayed, while others may progress faster than planned. The schedule, if properly prepared and updated, is a record of events that occurred on the project.

It can concisely represent many activities and reflect interrelationships and interdependencies among them. Effective scheduling practices reduce the likelihood of a dispute developing into lengthy arbitration or litigation.

The CPM can be very useful in resolving time-related claims [2,3,4,5]. In most cases, the CPM schedule can be used to resolve both delay and change-order disputes, provided that the schedule represents a reasonable and feasible plan and is supported by project records. No other viable alternative is currently available to owners and contractors for estimating the effect of a delay, change order, or any other disturbance.

#### Legal Recognition of CPM

CPM schedules have been used successfully as evidence in the presentation of claims and in litigation. Bar charts, while easy to follow, do not show all the interdependencies of the project activities. Several court cases have held that bar charts are not acceptable for determining the impact of delay. In the case of Minmar Builders, Inc., GSBCA 3430, 72-2BCA 9599 (1972), the Armed Services Board of Contract Appeals noted that:

Although two of the Appellant's construction schedules were introduced in evidence...neither was anything more than a bar chart showing the duration and projected calendar dates for the performance of the contractual tasks. Since no interrelationship was shown between the tasks the chart cannot show what project activities were dependent on prior performance...much less whether overall project completion was thereby affected. [6]

Courts have begun to emphasize the importance of CPM scheduling. The CPM network schedule reflects in detail which activities affect the performance of other activities. The cause-effect relationship of delays can therefore be analyzed using CPM. The Minmar court went on to state that:

In short, the schedules were not prepared by the Critical Path Method (CPM) and hence are not probative as to whether any particular activity or group of activities was on the critical path or constituted the pacing element for the project. [6]

The Minmar case showed that properly prepared network schedules are regarded as excellent evidentiary tools for analyzing delay claims. Adjusting the CPM as-built network is a method for analyzing which delays contributed to extending project duration.

#### Problem Statement

Numerous articles have been published concerning the value of CPM in settling claims or in litigation [2,6,7,8,9,10]. Few articles have detailed the means by which a CPM network can be best utilized to quantify the cause-effect relationship of delays.

Articles by Ponce de Leon [5] and Verderitsch [11] discussed the adjustment of CPM networks, but no precise methodology for this technique is readily available. Given the increasing number of delay claims and the high dollar value associated with them, a viable method for utilization

of CPM in resolving delay claims is important to the construction industry.

### Objective

The objective of this study was to document in detail a method that utilizes the CPM network for detailed analysis of schedule delays. This study also identified the advantages and limitations of the methodology.

The procedure for allocating time delays into the following categories will be shown:

1. Excusable, Noncompensable
2. Excusable, Compensable
3. Inexcusable

The report will also explain a methodology for evaluating acceleration cost responsibility. Excusable delays combined with acceleration of construction activities complicate claim resolution. The procedure will use the adjusted as-built network to assist in assessing this complex situation.

### Research Tasks

Three detailed tasks had to be completed to achieve the primary objective. First, the requirements for setting up a valid as-built schedule and categorizing schedule delays are presented. Second, a step-by-step procedure for analyzing and adjusting a CPM network is developed. The process for quantifying the significant delay damages is explained.

Finally, the methodology for evaluating acceleration is presented.

### Research Procedure

A review of pertinent articles, papers, and books was performed to provide insight into reviewing contract documents and project records to establish the framework and history of a construction project. The work of Rubin et al. [7] and Hester [12] provides guidelines for classifying the different types of delays.

Next, the methodology for analyzing and adjusting the CPM network was examined in detail. Articles by Werderitsch [11] and Ponce de Leon [5] provided the basics for the development of the step-by-step procedure to adjust a CPM network. The example as-built schedule presented by Ponce de Leon [5] is used to demonstrate the complete network adjustment methodology. Delays identified as critical in the sample project are analyzed to determine recovery for delay damages.

Finally, use of the adjustment technique for resolving acceleration claims was examined. A sample analysis of an accelerated schedule was prepared to demonstrate the procedure.

## Chapter II

### CONSTRUCTING THE AS-BUILT SCHEDULE

#### Introduction

Delays are a way of life in the construction industry. Construction claims based upon delays are frequently encountered and difficult to evaluate. Valid schedule delay analysis requires an accurate picture of the events that took place during the project. Before meaningful delay analyses can be done, several tasks must be accomplished:

1. Review of contract documents, project records, and documentation
2. Identification of the as-planned schedule
3. Identification and classification of delays by type
4. Development of the as-built schedule
5. Adjustment of the as-built schedule
6. Summary of delay impacts by type and assessment of liabilities

Tasks 1 through 4 are discussed in this chapter. Proper execution of these preliminary tasks is an essential prerequisite to obtaining a valid adjusted network. The methodology for network adjustment and measurement of delay (Tasks 5 and 6) is presented in the next chapter.

#### Analysis of Contract Documents, Projects Records, and Documentation

Before a delay claim can be analyzed, the contract documents must be carefully studied. A viable analysis



requires an appropriate interpretation of the contract clauses that pertain to delays.

The first step is to examine the contract as a whole, paying special attention to sections which discuss scheduling, suspensions of work, time extensions, change orders, scope of work, delay responsibilities, liquidated damages, notice requirements, etc. These clauses define the framework for granting time extensions, waiving liquidated damages, and recovering other delay damages.

All contract clauses pertaining to how time and money relate to delays should be consulted. "No damages for delay" is a common clause in public construction contracts. However, other provisions relating to monetary recovery for delays may be included. Payment of liquidated damages by the contractor to the owner should the contractor fail to complete the work by the contract date is one such clause. There may also be a clause stating that there will be no payment to the contractor for suspension of work (by the owner) or for costs resulting from a schedule acceleration.

Determining how the project events actually occurred requires detailed research of all project records and documents. Items such as letters, interoffice memos, daily reports, diaries, job meeting minutes, test reports, and schedules should be obtained because these provide the information needed to construct the as-built schedule accurately. All pertinent project information must be

gathered, organized, reviewed, and put into a usable and accessible format.

#### The As-Planned Schedule

The next task in the delay analysis process is to determine if the initial project schedule is a reasonable one. This may be a tedious and complicated process and will require considerable judgment by the reviewer. The as-planned schedule, if determined to be adequate and reasonable, will serve as the benchmark for measuring the contractor's actual performance.

Ideally, the contractor will have submitted a carefully prepared construction schedule at the beginning of the project, and the schedule will have been approved by the owner. Unfortunately, this situation does not always exist. The original schedule may have serious flaws, may not have been approved, or may not have been prepared in enough detail. When this occurs, an as-planned schedule must be developed to show how the project should have been reasonably planned and constructed [8].

#### Delay Identification and Classification

A key task in resolving delay claims is identifying and categorizing all delays encountered during a project. This includes not only those delays asserted in the contractor's claim, but all others as well. Parties to the contract must be aware of the total delay "package."

### Identification of Delays

Once the delay package is clearly understood, identifying the delays encountered during the project is accomplished through detailed research of the project records. This is often a very tedious process requiring close attention to the events that occurred during construction. Many delays are not readily identifiable. Comparison of project documents with the as-planned schedule may be of little value if the schedule was not followed from the outset of the project. The duration of the delay, when it occurred, and its root cause are the significant facts that must be extracted from the project documents.

### Categories of Delays

Next, delays must be categorized by type, based upon who was responsible for causing the delay. The categories for delays presented below are based upon the federal model of classification. Courts have frequently relied upon this model in cases pertaining to schedule delays. The principal types of delays are presented in Table 1.

Excusable/Nonexcusable Delays. There are two main categories of delay, excusable and nonexcusable. If delays are excusable, they can be further broken down into excusable/compensable and excusable/noncompensable categories. "Compensable" is understood to mean compensable to the contractor.

Table 1  
Principal Types of Delays [12]

<u>EXCUSABLE</u>		<u>NONEXCUSABLE</u>
Compensable	Noncompensable	Noncompensable to Contractor and Compensable to Owner
1. Delays Caused by Owner <ul style="list-style-type: none"> <li>- Lack of coordination</li> <li>- Holds or suspension</li> <li>- Failure to provide access</li> <li>- Owner-furnished material not available</li> <li>- Major change</li> <li>- Delays in approval of change orders, shop drawings, schedules</li> <li>- Stop work order</li> <li>- Inadequate information and supervision</li> </ul>	1. Delays Out of Contractor's and Owner's Control <ul style="list-style-type: none"> <li>- Acts of God</li> <li>- Floods</li> <li>- Public enemy</li> <li>- Other contractors</li> <li>- Sovereign authority</li> <li>- Epidemics</li> <li>- Strikes</li> <li>- Embargoes</li> <li>- Weather</li> <li>- Subcontractors and suppliers</li> </ul>	Delays for Which Contractor Is Responsible <ul style="list-style-type: none"> <li>1. Subcontractor delay</li> <li>2. Financial ability</li> <li>3. Failure to perform               <ul style="list-style-type: none"> <li>- Failure to mobilize and man the job</li> <li>- Poor workmanship</li> <li>- Failure to order materials and equipment</li> <li>- Failure to schedule the work</li> <li>- Inadequate supervision</li> </ul> </li> </ul>
2. Changed Conditions		
3. Differing Site Conditions		
4. Acceleration <ul style="list-style-type: none"> <li>- Directed</li> <li>- Constructive</li> </ul>		

1. Excusable Delays: These are delays over which the contractor had no control. The contractor is entitled to an extension of time under the contract. They are often cited in the contract documents. Examples could be failure of the owner to provide site access, written or constructive change orders, or delays arising from events beyond the control of the contractor, such as unusual weather, labor strikes, acts of God, and so on. To be excusable, the delay must be on the critical path of the network describing the project schedule. In other words, the delay must directly affect the ultimate completion of the job. Correspondingly, if the delay, whatever the cause, is not on the critical path and thereby not affecting the ultimate completion date of the work, there will be no compensation. It must be noted here that the critical path may shift. A delay that is not immediately seen as being on the critical path may ultimately affect the completion date. For example, concrete work not originally on the critical path may be delayed and interfere with the start of a critical activity. The critical path would then shift to include the concrete activity. This is a good reason to track the critical path of a job on a regular basis.

(a) Excusable/Compensable: These delays are due to some act or omission of the owner. Lack of site access or late arrival of owner-furnished material or

equipment are two examples. In such cases, the contractor would be entitled to damages for extra costs incurred and a time extension unless there is a valid contract clause barring such recovery.

(b) Excusable/Noncompensable: These are delays for which neither party is at fault: acts of God, epidemics, etc., as set forth in the delay clause. Time extension is the only remedy for such delays.

2. Nonexcusable Delays: Delays caused by the contractor are nonexcusable. These could include failure to coordinate the work, too few workers on the job, late arrival of equipment furnished by the contractor, low productivity, defective work that must be removed and replaced, etc. Such delays could be compensable to the owner in the form of liquidated or actual damages paid by the contractor for late completion, or could be the basis for contract termination by the owner. The owner could also direct the contractor to accelerate the work.

#### Preparing the As-Built Schedule

A simultaneous task during the claim analysis phase is the preparation of an as-built schedule depicting the actual sequence of events which occurred during the construction of the project. The as-built schedule is developed from a detailed examination of the project records: specifically,

the daily job diaries, minutes of project meetings, and written correspondence. Once the delays have been identified and categorized, the as-built schedule can be completed by inserting the identifiable delays [8].

#### Delay Representation

In constructing the as-built schedule, delays caused by poor contractor productivity are simply expressed in the activity duration. Other delays are shown as activities immediately preceding or following the work which is directly affected. An activity that experienced several intermittent delays (i.e., rain) can be grouped into one consecutive delay activity at the end of the activity it affected. This will vary the start and finish days slightly. Most delays will not be readily evident in project records.

#### Substantial Completion

When project completion is delayed, substantial completion (meaning that the facility is ready for owner use) needs to be established. The project may continue for a significant amount of time without having a serious impact upon the intended use of the facility. Substantial completion may be referred to in the contract documents or determined by certificates of acceptance or occupancy of the facility.

### As-Built Schedule: Construction Steps

The basic steps for constructing an as-built schedule are summarized as follows:

1. Conduct a detailed review of project records and documents and compile pertinent data
2. List and categorize all delays that occurred during the project
3. Draw the as-built network:
  - (a) Show activities in their as-built time frames, except when embedded delays need to be shown
  - (b) Place excusable delays immediately preceding or following the activities affected
  - (c) Show suspensions of work as activities on the as-built schedule
  - (d) Add activities that show work amended by change orders
  - (e) Place inexcusable delay activities on the network.

### Summary

The as-built schedule is the baseline from which the effects of delays are measured. An inaccurate schedule has a serious impact upon the validity of a delay analysis.

This chapter has detailed the tasks necessary to prepare the as-built schedule. The next chapter will present the methodology for adjusting the as-built schedule and measuring the impact of the significant delays.



### Chapter III

#### AS-BUILT NETWORK ADJUSTMENT

##### Introduction

CPM schedules are extremely valuable tools in claim presentations. They can be used to show the effect of a change order or a suspension of work, to offset the imposition of liquidated damages, or to demonstrate that a termination for default was improper.

This chapter will present the methodology for effectively adjusting a CPM schedule and assessing delay damage. Adjusting the network involves reducing the number of days required to complete the project. This is accomplished by removing delay activities located on a network's critical path(s). The adjustment process continues until all delays are removed from at least one critical path. The adjusted schedule should then reflect the shortest period of time required to construct the project had no delays been present. Delays that were removed in the adjustment process can be grouped into categories. The total number of days that each delay category contributed to extending the project can then be determined. Time extensions, compensation, and liquidated damages can then be assessed.

Schedule delay assessment is a variant process. Contract conditions, variations in assessing concurrency of delays, and interpretation of delay responsibility are variables that affect the outcome of schedule adjustment.

With this in mind, the methodology that will be presented covers the basic steps necessary to obtain an adjusted CPM schedule. Adjustment of a specific CPM schedule must be performed within the guidelines of the contractual documents to provide a meaningful analysis.

#### Adjustment Methodology

The objective of adjusting a network is to reduce the as-built schedule to a point where no delays are present in at least one critical path. The as-built schedule is adjusted by deducting both excusable (noncompensable and compensable) and nonexcusable delays from the as-built critical path(s). The purpose of this section is to present the methodology for computing the adjusted as-built schedule. This will establish excusable contract completion.

#### Listing of Steps

The reduction or adjustment process is essentially a form of "crashing" the CPM network [13]. As the duration of a critical delay activity is reduced, the critical path will be shortened. Note that the term "critical delay activity" refers to any type of delay that is located on a critical path. The methodology for obtaining the final adjusted network is iterative and is comprised of five main steps in each iteration. The basic steps are enumerated below:

1. Determine the current critical path(s)
2. Select the delay activity(s) on the critical

path(s) to be reduced

3. Determine the maximum possible reduction in the project duration
4. Analyze the network to determine reduction restraints
5. Reduce the appropriate delay activity(s) and update the network accordingly.

#### Analysis of Steps

Step 1: Determine the current critical path(s). For the first iteration of the adjustment process, the critical path is established from the original as-built schedule. As the project duration is reduced, other paths in the network will become critical. Critical paths are identified by a succession of zero link lags from the starting activity to the completion activity. Zero link lags represent no delay between the finish of an activity and the start of the succeeding activity. Shorter critical paths that branch off an already existing critical path can also be formed in the reduction process. All current critical paths must be identified to determine if delays are present in each path.

Step 2: Select the delay activity(s) on the critical path(s) to be reduced. In some instances, critical paths may join together and reduction in one critical delay activity will result in a reduction in both paths. Excusable delays are considered first. When no excusable delay remains in one of the critical paths but inexcusable

delays are present, then the two types must be reduced concurrently. This situation will be shown during the adjustment of the sample project in a later section. The selection process is an important step in the methodology. Depending upon which activity is removed, different outcomes can result. However, the critical path that determines the final adjusted network eventually must have all delay activities removed.

Step 3: Determine the maximum possible reduction in the project duration. The objective of this step is to determine the minimum duration value of the activities chosen for reduction. For example, if activities A and B are chosen for reduction in a particular cycle, and activity A has a duration of 15 days and B has a duration of ten days, then the maximum reduction that can take place in the cycle is ten days.

Step 4: Analyze the network to determine reduction restraints. The maximum possible reduction determined in Step 3 may be restrained by the network logic and lag relationships within the various paths. The reduction of the project duration is limited because an additional path has become critical. Further schedule compression cannot occur unless the reduction is associated with an activity on the new critical path. Therefore, the project duration cannot be shortened by the full duration of the delay activity(s) selected for this iteration. To determine if

any restraints are present, the network must be analyzed. This is best accomplished by actually adjusting the network.

The network adjustment process involves shortening the duration of the selected delay activities. The amount of reduction is subtracted from the value that indicates on what workday the activity was completed (finish workday value). The new value for the finish workday is then indicated above the crossed-out, original finish workday value.

The next step is to adjust the succeeding activities. An activity directly succeeding the reduced activity with a zero link lag results in the start and finish workday values being similarly reduced. Again, the previous value is crossed out and the new workday value printed above. If the duration of the original delay activity is reduced to zero, and thus eliminated, then the succeeding activity has a start workday value equal to its predecessor's start workday value. Figure 1 shows this process. Activity B is reduced by four days (eliminated), and activity C would then have a start workday value of four. The reduction of the start and finish workday values continues along the critical path until the completion activity is reached.

Positive link lags that are connected with the portion of the critical path affected by the reduction will have their respective lag values decreased by the amount of the reduction. This is where a restraint is most likely to be encountered. If the lag value is reduced to zero and no

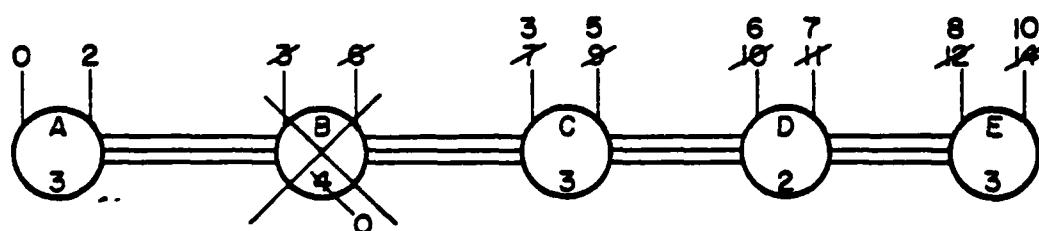


Figure 1. Activity Reduction Process

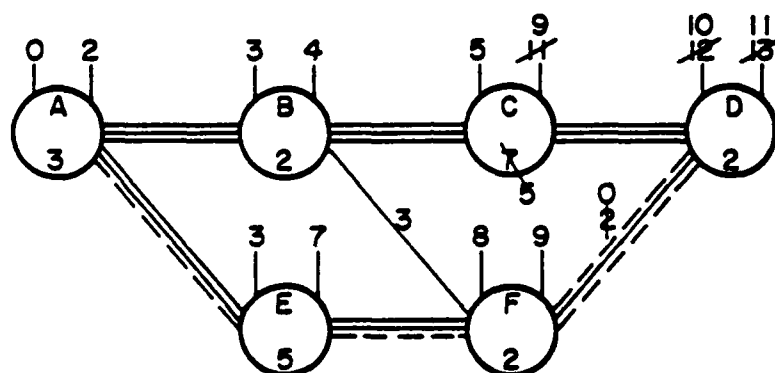
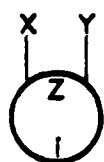


Figure 2. Example of Reducing Lag Value



X = Workday activity started

Y = Workday activity completed

Z = Activity node number

I = Duration of activity in workdays

other lag is present in the path, then this path has become critical. If the adjustment produces a negative lag value, then the reduction in project duration is too great and is limited to the link lag value. Figure 2 illustrates this effect upon lag values. The reduction of activity C by two days requires the reduction of activity D due to the zero lag between the activities. Activity D now starts on the tenth workday. Activity F is not affected by the reduction of activity C, so its start and finish days are unchanged. The lag between the finish workday for activity F and the start workday for activity D has been reduced by two. Link lag F-D is now a zero link lag. A double line indicates a zero link lag.

The two-day lag between activities F and D imposes a limit on the reduction of the network. Although activity C has five more days of duration, only a two-day reduction can be performed. The removal of the two days of lag in link F-D creates a new critical path, A-E-F-D. No further reductions to the project duration can be achieved unless both paths are shortened.

The value of link lags that branch off from the affected part of the critical path may increase or remain the same. Figure 3 reflects a situation where a link lag value is increased during a network reduction. Activity B is reduced by one day, but the network logic does not affect activity F in the reduction process. The lag value for link B-F is then increased from three to four days. Figure 4

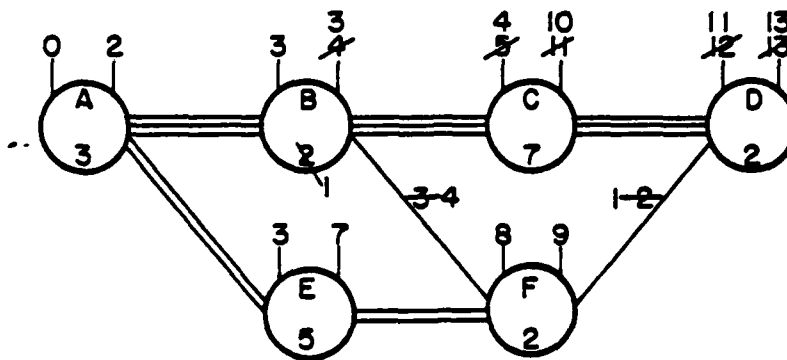


Figure 3. Example of Increasing Lag Value

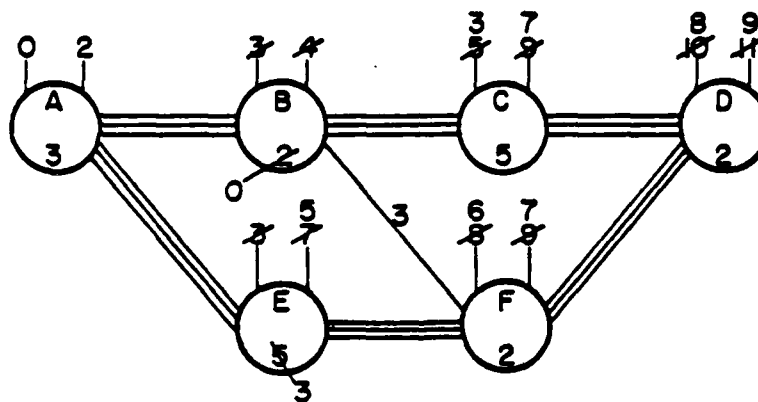
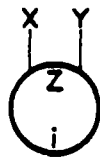


Figure 4. Example of Unchanged Lag Value



X = Workday activity started

Y = Workday activity completed

Z = Activity node number

i = Duration of activity in workdays



presents a situation in which a link lag value remains the same. Activities B and E are reduced by two days. The zero link lag relationship between activities E and F forces the reduction in activity F's start and finish workday values. Since activity B's duration is also being reduced, the three days of lag on link B-F remains unchanged.

Step 5: Reduce the appropriate delay activity(s) and update the network accordingly. The network analysis is often accomplished by actually performing the reduction to see if restraints are present. Step 5 is a follow-through to ensure that the affected portions of the network are correctly adjusted. Included in this step is the identification of any new critical paths.

The larger the network and the greater the amount of delays, the more tedious the adjustment process becomes. The number of iterations required to obtain the final adjusted network depends upon the network size and logic as well as the number and duration of delays encountered on critical path(s).

#### Example of Excusable Delay Calculation

A simple example of an excusable delay calculation described by Werderitsch [11] is presented below to provide a clear understanding of the network adjustment process. The example details the methodology for calculating a time extension based upon two excusable delays: one is on the critical path and the other is not.

In Figure 5, paths A and B represent actual durations of construction activities leading to actual project completion (AC), which is 30 days beyond the contract completion date (CC). Delays X and Y are identified as excusable and not related. Path A is critical. The task is to determine the allowable time extension due to the excusable delays.

In analyzing the example, delay X is addressed first because it is on the critical path. After identification of the critical path and the selection of the activity for reduction, the next step is to deduct delay X as much as possible, or until another path becomes critical. Figure 6 shows the configuration of the schedule after ten days of delay X have been deducted. This reduces the ten days of total lag from path B to zero and results in both paths A and B becoming critical.

The process is then repeated. Since there are two critical paths, delays on both paths will have to be deducted simultaneously. These delays need not occur in the same time frame. In the example, 20 days remain for delay X and 15 days remain for delay Y. Both delays are simultaneously reduced by the smaller amount. This is shown in Figure 7. With each successive reduction of delay days, the other paths in the network must be reviewed to determine if they have become critical. In this example, a 25-day time extension is allowable instead of the 30-day extension requested.

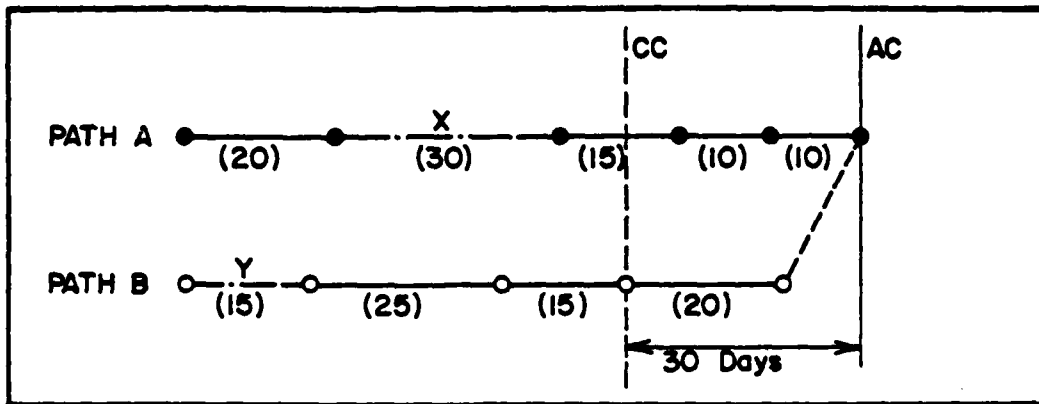


Figure 5. As-Built Condition [11]

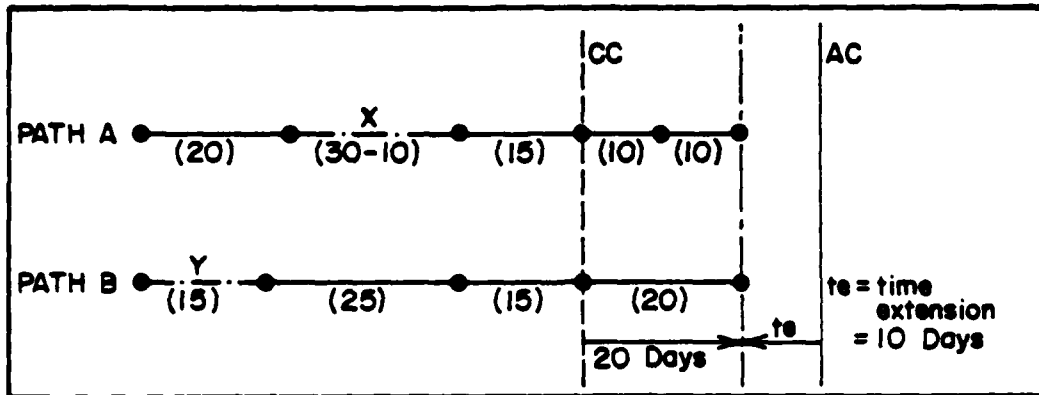


Figure 6. Ten-Day Delay Reduction [11]

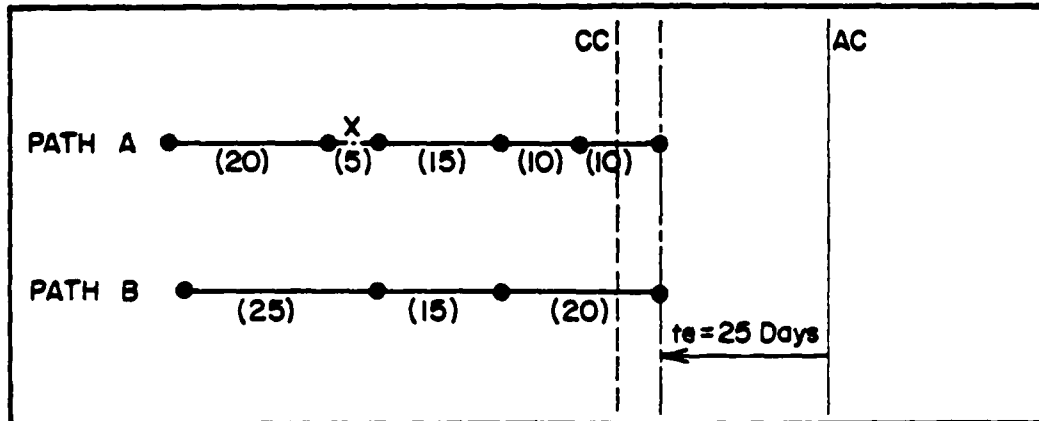


Figure 7. Final Adjusted Condition [11]

### Description of Sample Project

To clarify the steps in adjusting an as-built schedule, a sample project will be presented. The hypothetical network was originally developed by Ponce de Leon [5].

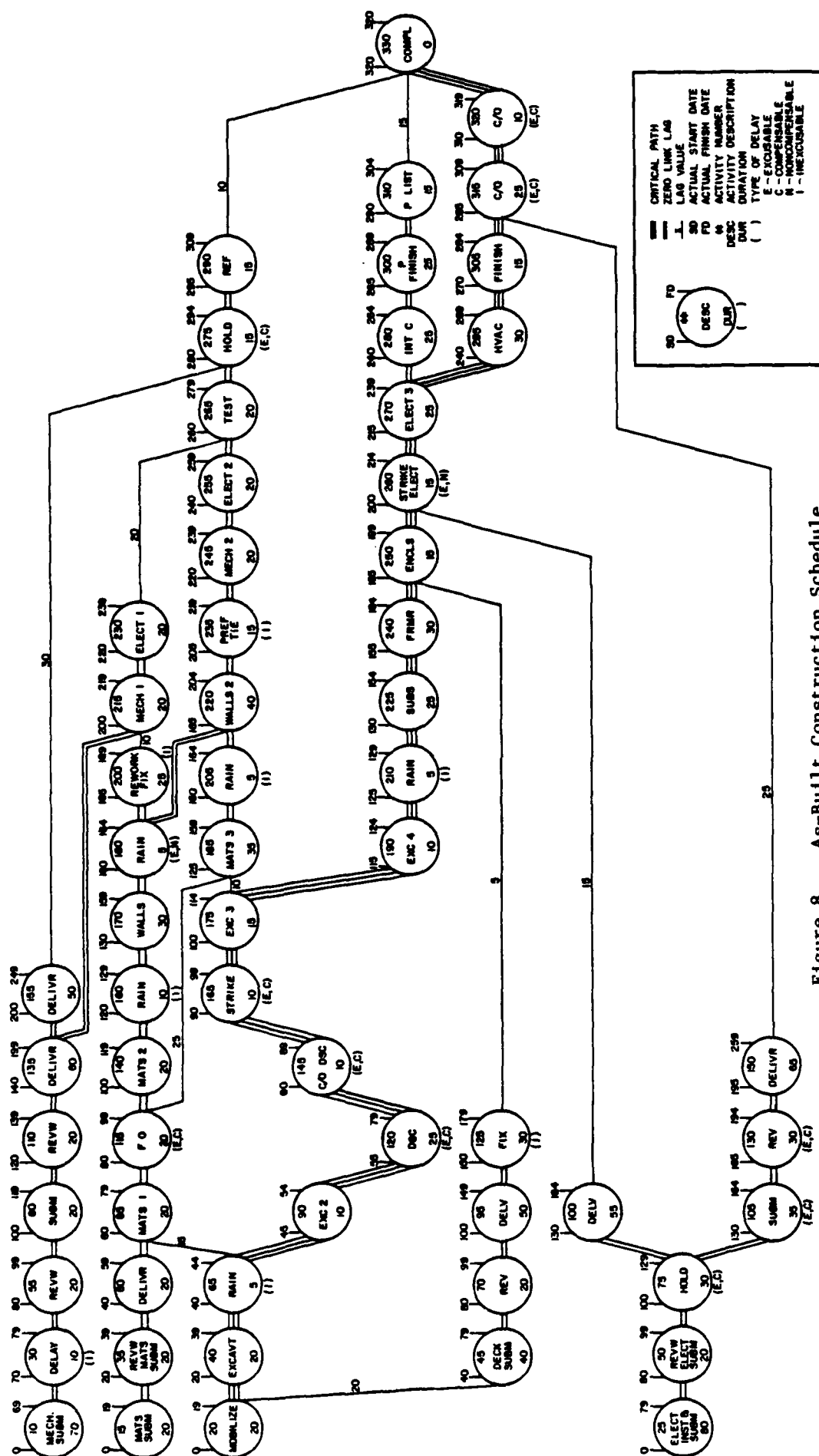
### Project Review

Figure 8 reflects a 320-day as-built schedule for a 240-day construction contract. This CPM diagram shows identifiable contract activities: as-bid scope of work, excusable delays, suspensions of work, occurrences of conferring site conditions, work amended by change order, and inexcusable delays.

Activities representing the as-bid scope of work are shown in their as-built time frames (i.e., from actual starts to actual finishes) except when embedded delays need to be shown. For instance, in the case of rain, start and finish dates vary slightly from the as-built dates. The intermittent rain delays that occurred during an activity are accumulated and shown on the network after the affected work. These rain activities account for no-work days as well as slowdowns due to working under unfavorable weather conditions.

### Delay Categories

Identifiable delays in Figure 8 are categorized below. The delay classification that follows is in accordance with the Ponce de Leon example [5].



**Figure 8. As-Built Construction Schedule**

Activity  
Number

Type Of Delay

EXCUSABLE - COMPENSABLE

1. Delays Caused by Owner

- |          |  |
|----------|--|
| 75       | 30-day hold on the processing of instrumentation shop drawings.  |
| 115      | 20 days to process a field order to correct a design defect in the tank base mats and to perform the associated work (change order).   |
| 105, 130 | 65 days for instrumentation resubmittals and review (change order).  |
| 165      | Ten days of the 20-day Teamsters' strike are considered compensable because two remaining excavation activities would have been completed prior to the strike had it not been for the differing site conditions. |
| 275      | 15 days of no access to existing facilities for equipment refurbishing.  |
| 315, 320 | Total of 35 added days of instrumentation work, including tie-ins and testing (change order).  |

2. Differing Site Conditions

- |     |  |
|-----|--|
| 120 | 25 days due to a differing site condition (poor soil) encountered during excavation. |
| 145 | Ten days to correct problems caused by poor soil conditions (change order).          |

## EXCUSABLE - NONCOMPENSABLE

Delays Beyond Contractor and Owner's Control

- 180 Five days out of a total of 15 days shown  
(Activities 160-170-180) are unusually severe and  
are considered excusable.
- 260 15-day strike activity reflects the impact of an  
electrician's strike upon electrical work which  
could have been started on the 200th day.

## INEXCUSABLE

Delays for Which Contractor Is Responsible

- 30 Ten days for late submittal of mechanical  
drawings.
- 125 30 days for refabrication of roof decks which were  
delivered bowed.
- 200 25 days spent correcting some defective concrete.
- 235 15-day restraint on mechanical work due to failure  
of the subcontractor to add another crew to work  
on two tanks at same time.

Excusable delays such as strikes are shown as activities immediately preceding or following the work which was directly affected. It should be emphasized that theories pertaining to what is inexcusable, excusable, and compensable are based upon the pertinent contract language.

When working with the as-built schedule, the only delays that matter in terms of measuring total impact upon the contract are those that are on the as-built critical

path(s). The adjustment process can begin once the as-built network has been constructed and all identifiable delays have been classified. The process for this example involves deducting delays from the as-built critical path(s) until no delays are present in at least one critical path.

#### As-Built Schedule Adjustment

Before the adjustment process begins, the order of priorities for selecting delays to be removed must be specified. Also, theories related to the concurrency of delays are presented to assist in understanding the results obtained during the network adjustment. The reduction process is iterative and applies the steps detailed earlier in this chapter.

#### Delay Selection Logic

Adjustment of the as-built network can produce various outcomes relative to the various types of delays. The outcome is based upon the order of priorities used for selecting which delay to reduce during each iteration. Step 2 in the adjustment process requires selecting the delay(s) to be reduced in the iteration. When multiple delays occur on a critical path, one must decide which delay to reduce.

The order of priority used in this report for choosing an activity to reduce is as follows:

1. Excusable, noncompensable activities
2. Excusable, compensable activities relating to suspension of work



3. Excusable, compensable activities relating to change-order work

4. Inexcusable delays.

When two or more delays from the same category are present on a critical path, the last one is usually chosen for ease of calculation. One exception to this is when the reduction of an earlier delay would result in the shortening of multiple paths.

The purpose of the adjustment process is to remove all delays from a critical path. A different order of priority for selecting delays may result in different measurement outcomes. However, the total reduction to the project duration would remain the same.

#### Concurrent Delay Reductions

When delays from different categories are reduced in the same iteration, special theories are applied. These theories dictate the category to which the delay reduction is to be assigned.

The theories summarized below are detailed in a seminar workshop package published by Project Management Associates [14]. They are based upon interpretation of federal contract clauses and have been corroborated by several court decisions [14].

1. An inexcusable delay reduced concurrently with an excusable, noncompensable delay yields a net excusable, noncompensable delay

2. An inexcusable delay reduced concurrently with any type of excusable, compensable delay yields a net excusable, noncompensable delay
3. An excusable, noncompensable delay reduced concurrently with a suspension-of-work compensable delay yields an excusable, noncompensable delay
4. An excusable, noncompensable delay reduced concurrently with change-order or differing-site-conditions (corrective work) compensable delays results in an excusable, compensable delay.

#### Adjustment Process

Knowing the theories of concurrent delays and the order of priority for removing delays, one can begin the adjustment process.

First Iteration. The first step in adjusting the network requires identification of the critical path(s) to determine which activities can be reduced. In Figure 8, the critical path can be identified as the path with all zero link lags. It is indicated by the triple lines between activities.

By looking along the critical path, the delay activities can be observed. Activities 65, 120, 145, 165, 210, 260, 315, and 320 are identified as the delay activities on the critical path. Activity 260, electrical strike, is chosen for reduction because it is the only excusable, noncompensable activity to occur on that path.

Although this activity has 15 days available for reduction, the network must first be analyzed to determine if any restraints exist that would preclude the full reduction.

A limit to the number of days available for reducing the project duration is encountered when another path becomes critical. Project duration cannot be reduced further unless activities in both critical paths are reduced simultaneously. An as-built network path becomes critical when no lag is present in the path. It can be seen that a reduction of activity 260 would affect the lag values of two paths in the network. First, the path consisting of activities 15-35-60-85-115-140-160-170-180-220-235-245-255-265-275-290-330 is affected. It contains ten days of lag. Second, the lower path consisting of activities 25-50-75-105-130-150-315-320-330 is affected. It contains 25 days of lag. The ten days of lag on the first path between activities 290 and 330 therefore limits the 15 days of reduction available to activity 260. A ten-day reduction in the project duration would make this upper path critical. Therefore, the maximum reduction for this iteration is ten days.

The actual reduction process involves reducing the duration of activity 260 by ten days. Activities with zero link lags, indicated by a double line, that are successors to activity 260 have both their start and finish project workday values decreased by ten days. As determined in the network analysis step, the link lag 290-330 is reduced from

ten to zero. This is shown in Figure 9. The dotted line indicates the newly created critical path. The lag value of the lower most path has been reduced by ten days and is now 15. The path that branches off the already existing critical path (activities 270-280-300-310-330) has 15 days of lag. Activities 280, 300, and 310 have their start and finish values reduced by ten days due to the successive zero lag relationship with the critical path. Since activity 330 was also on the original critical path its start and finish values were also reduced by ten days. Therefore, the 15 days of lag between activities 310 and 330 does not change for this iteration.

The removal of ten days of excusable, noncompensable delay from activity 260 has reduced the project duration from 320 days to 310 days.

Second Iteration. Further shortening of the project duration must be accomplished by the simultaneous reduction of both critical paths. Analysis of both paths in Figure 9 indicates that only one excusable, noncompensable delay exists on each path. Activity 180 on the upper critical path and activity 260 on the lower critical path are then chosen for reduction. The maximum possible reduction is the minimum duration value of the two activities. Since both activities have a duration of five days, this is the possible amount of reduction provided no restraints are present.

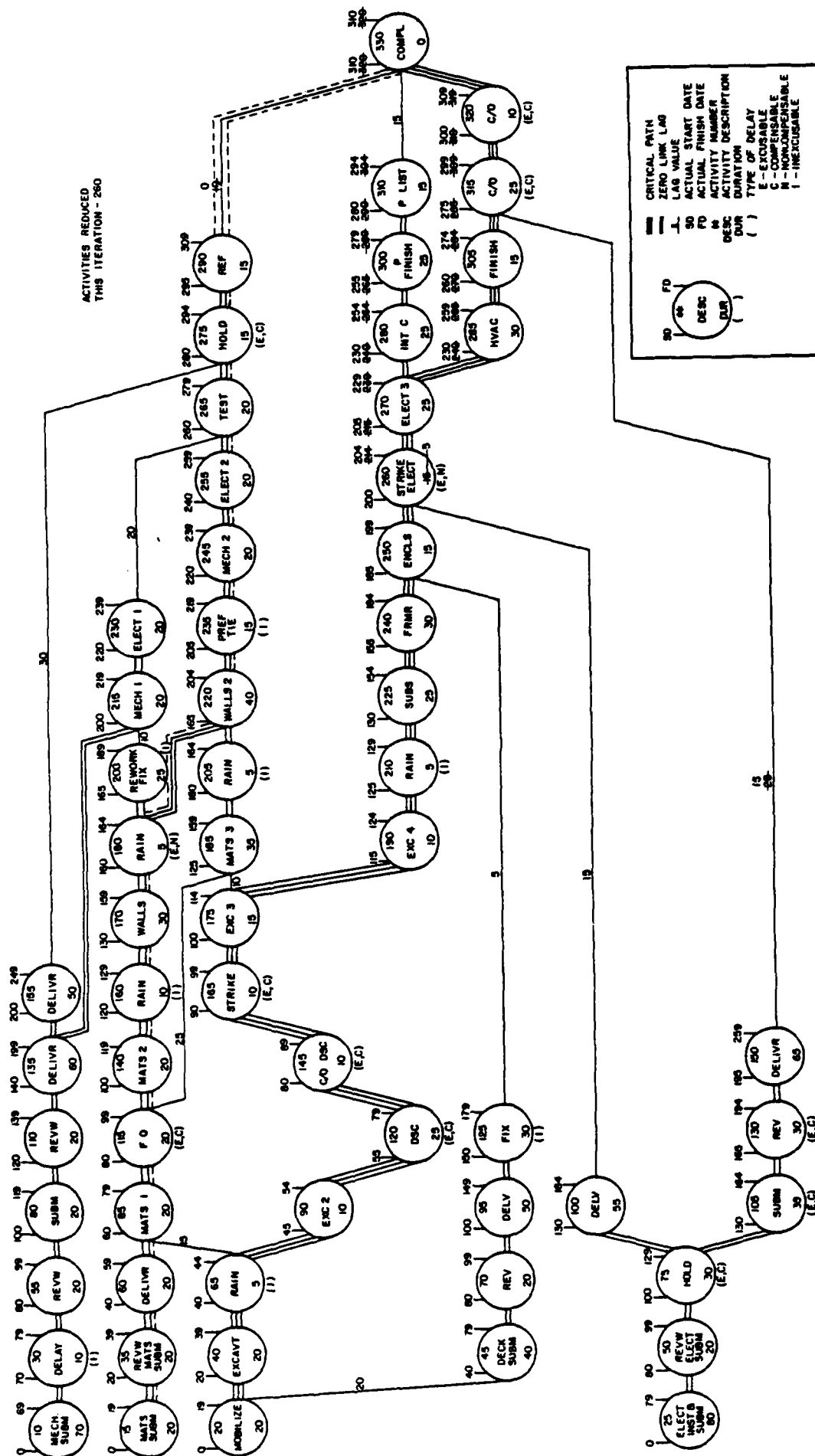
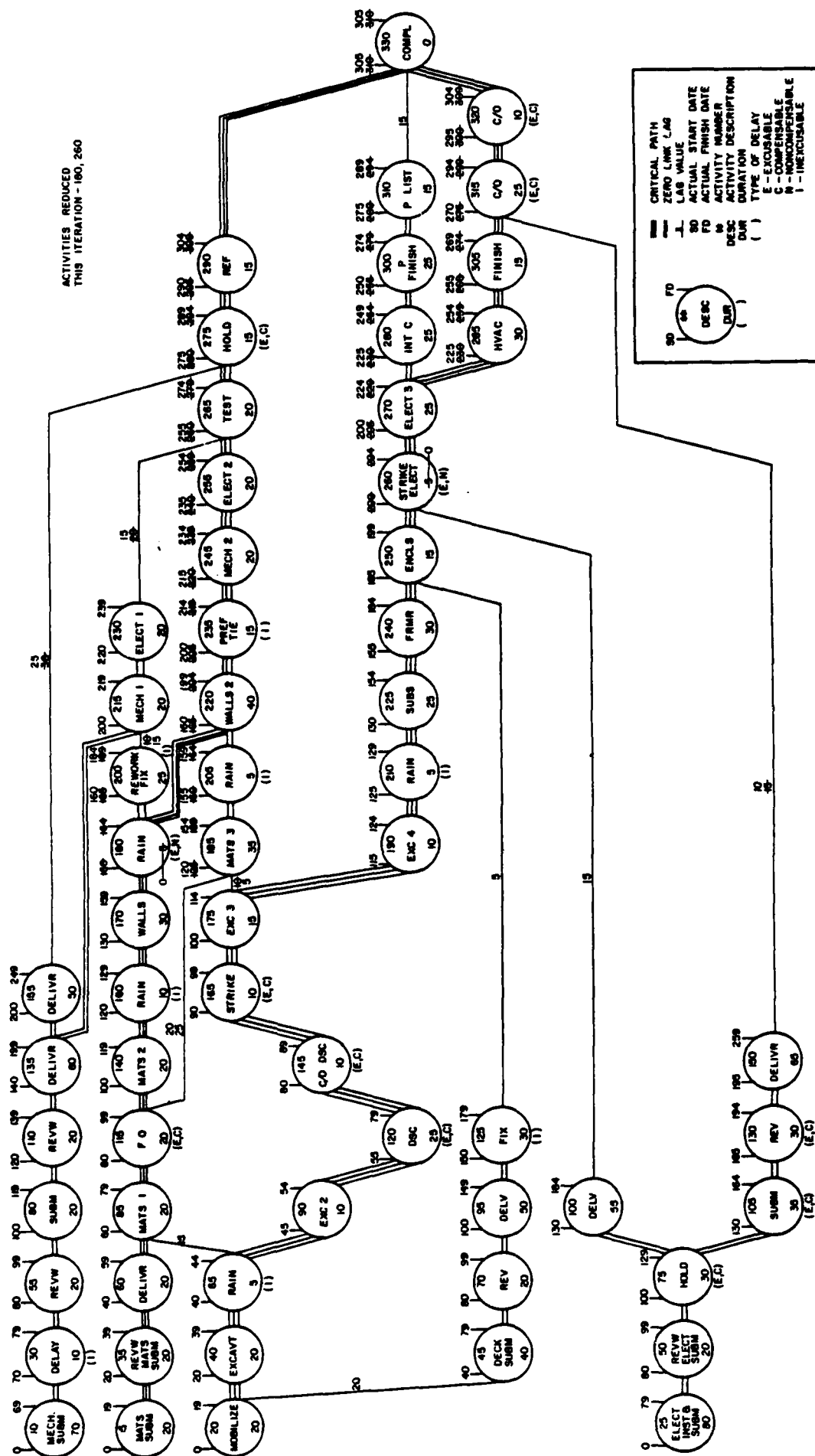


Figure 9. Adjusted Network After First Iteration

Each critical path and paths connecting into them are studied to determine if any restraints are encountered that will preclude a five-day reduction. Positive link lags are analyzed closely to determine if any are reduced to zero by the adjustment. Since activity 180 will be eliminated entirely, four link lags (115-185; 175-135; 155-275; 230-265) will be reduced by five days. However, none will become zero link lags. Link lag 150-315 will also be reduced due to the elimination of activity 260. Although several lags are affected, no restraints are encountered, and the full reduction of five days can be made.

The new network is shown in Figure 10. No new critical paths have been formed by the five-day adjustment. The project duration is decreased to 305 days by the removal of five days of excusable, noncompensable delays.

Third Iteration. After the elimination of activities 180 and 260, no additional excusable, noncompensable delays exist on either critical path. Excusable, compensable delays are now considered for reduction. Following the selection logic previously presented, suspension-of-work delays are considered first for reduction. Referring to Figure 10, two activities that meet this condition are activity 275 (hold by owner) and activity 120 (differing site condition). The maximum possible reduction is controlled by the 15-day duration of activity 275. No restraints are present for the upper critical path. Analysis of the lower critical path reveals a ten-day limit



**Figure 10. Adjusted Network After Second Iteration**

imposed by the lag on the link 150-315. The path 25-50-75-105-130-150-315 can only accommodate a ten-day reduction until it becomes critical. The lag on the deck submittal path, 20-45-70-95-125-250, is reduced from five to zero days; however, this path does not become critical because the additional five days of reduction is absorbed by the 20-day lag between activities 20 and 45. The link lag between activities 100 and 260 is reduced from 15 to five days.

Figure 11 reflects the results of the adjustment process. After the adjustment is made, a new critical path is added through activities 25-50-75-105-130-150-315-320-330. The project duration is reduced to 295 days by the removal of ten days of excusable, compensable (suspension) delays.

Fourth Iteration. Equal reductions to the three critical paths must now be accomplished. The two activities that were shortened in the last iteration, e.g., activities 120 and 275, can be reduced further. The hold activity (75) can be chosen for reduction from the newly formed lower path. The maximum possible reduction, considering these three activities, is the five days associated with activity 275.

From Figure 11, it is determined that no restraints exist. Therefore, the project duration can be reduced by the removal of five days of excusable, compensable (suspension) delay. Figure 12 shows the new network. Note



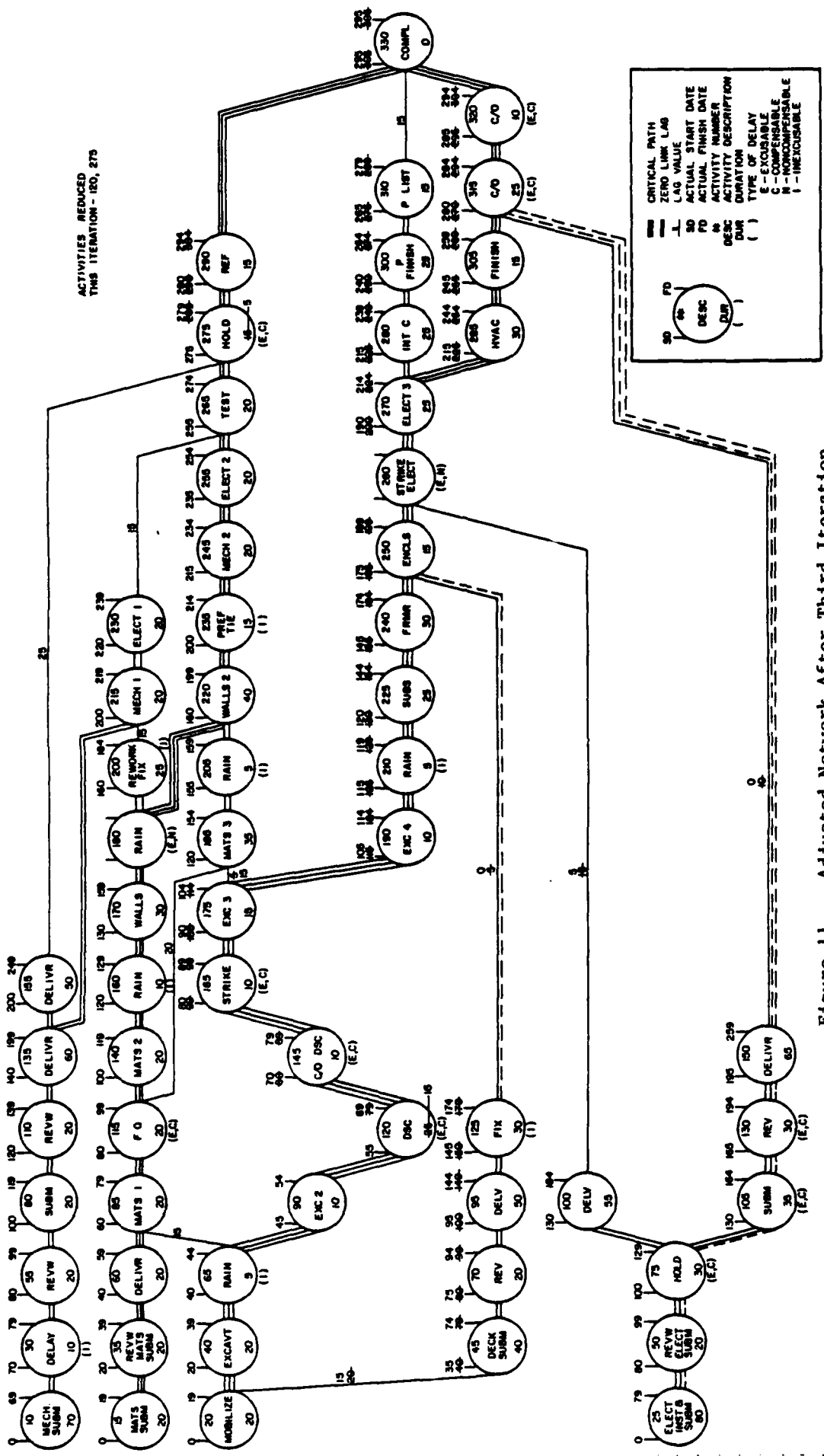


Figure 11. Adjusted Network After Third Iteration

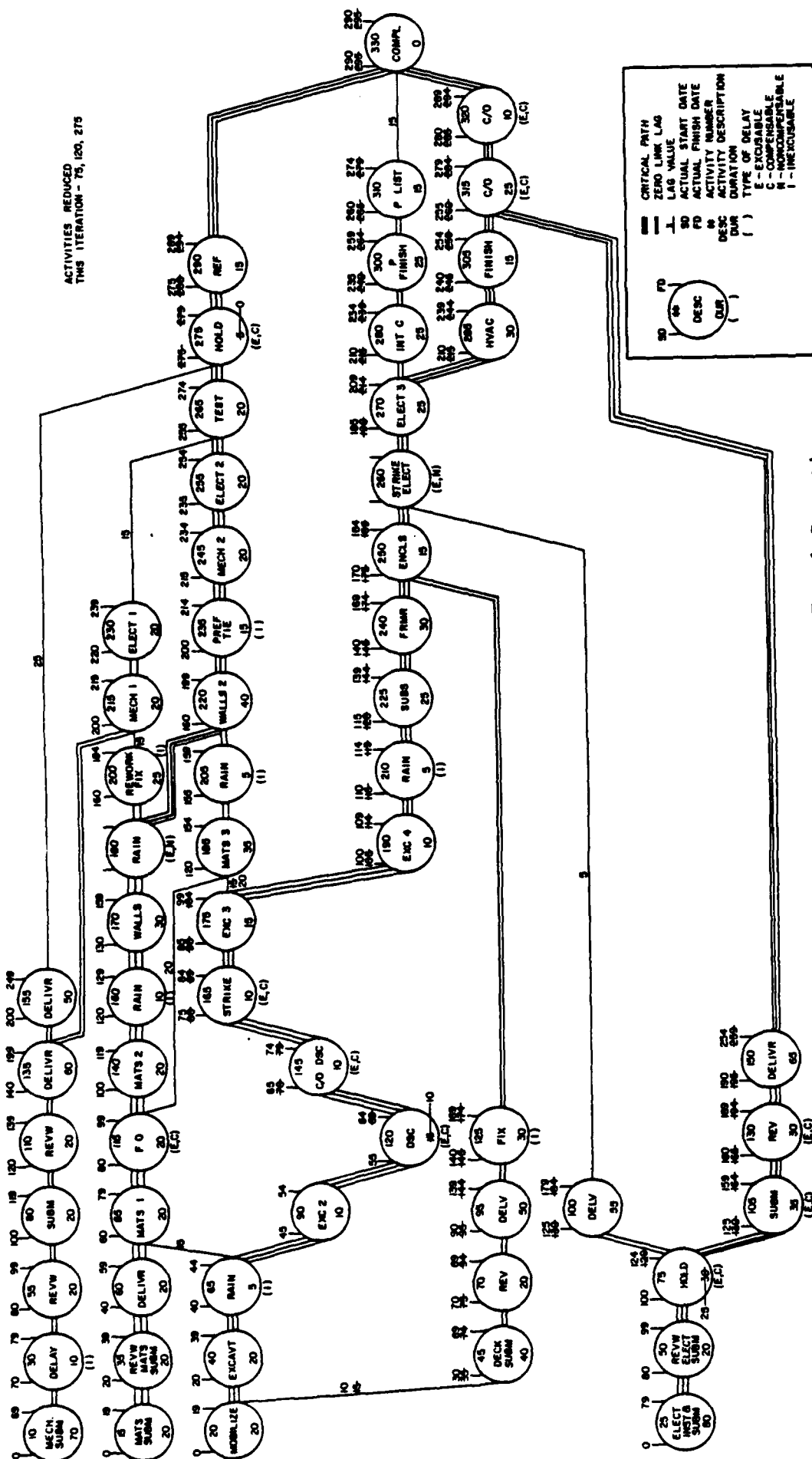


Figure 12. Adjusted Network After Fourth Iteration

that several lag values have changed, and that the project duration is now 290 days.

Fifth Iteration. Further reductions can be achieved by eliminating the ten-day tie-in and testing activity (320) added by the change order. This will reduce both the middle and lower critical paths. The only remaining excusable delay in the upper path is the field order activity (115). This activity can be reduced 20 days.

Again, the network is studied to identify logic restraints. No restraints exist in the upper path.

Relative to activity 320, few subsequent activities are affected. One effect of reducing activity 320 by ten days is a decrease in the link lag value for 310-330. The new link lag is now five days. The removal of the ten days of excusable, compensable (change-order) delays makes the project duration 280 days.

Sixth Iteration. From Figure 13, activities 115 and 315 are selected for adjustment. Activity 115 must be chosen because it is the only remaining excusable delay on the upper critical path. Activity 315 is chosen because it affects both the middle and lower critical paths. Activity 115 can be reduced by ten days.

Analysis of the network indicates a five-day reduction limit resulting from lag values at the 230-265 link and the 310-330 link. Both values become zero when the network is reduced by five days. Two new critical paths are then

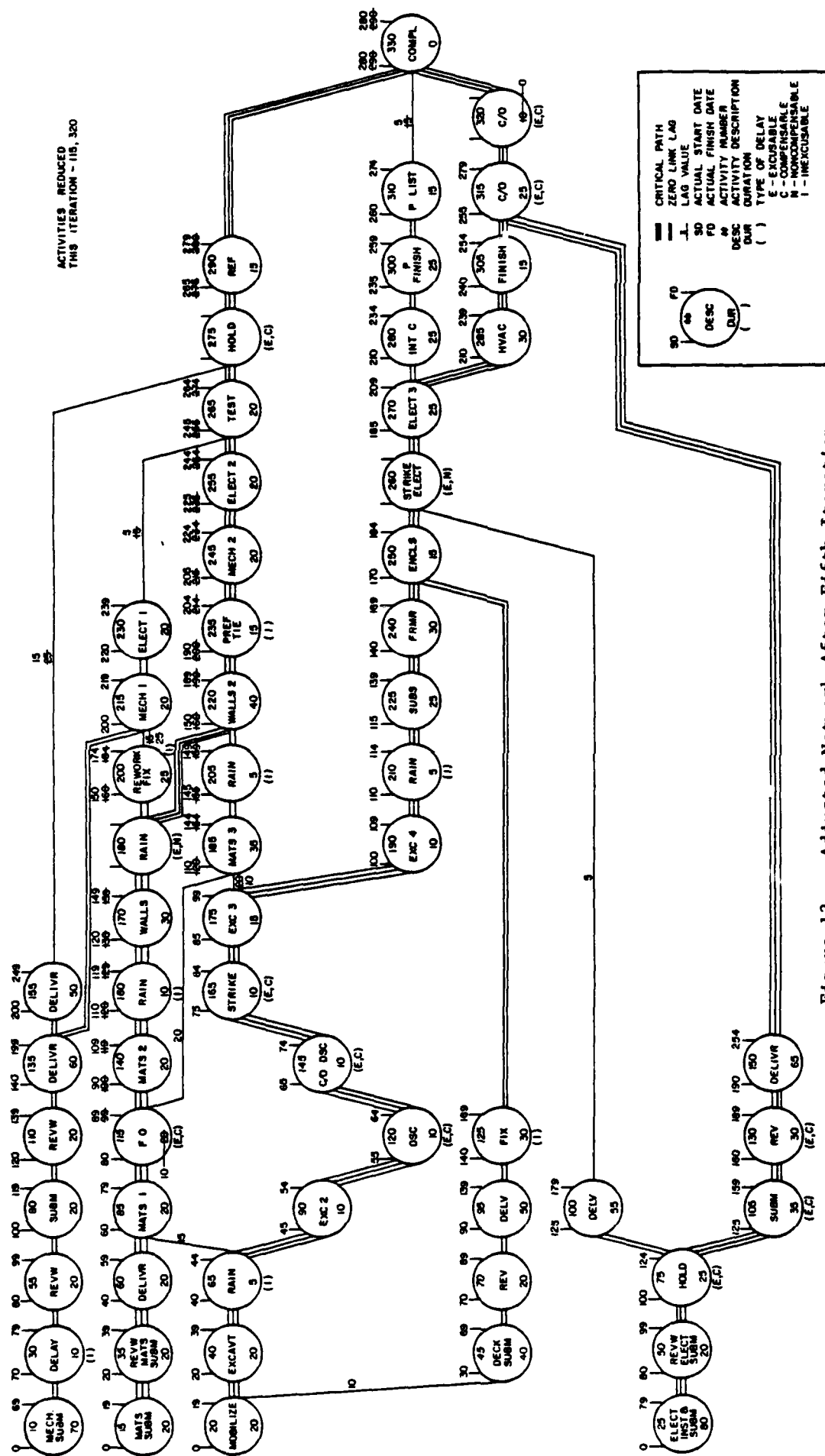


Figure 13. Adjusted Network After Fifth Iteration

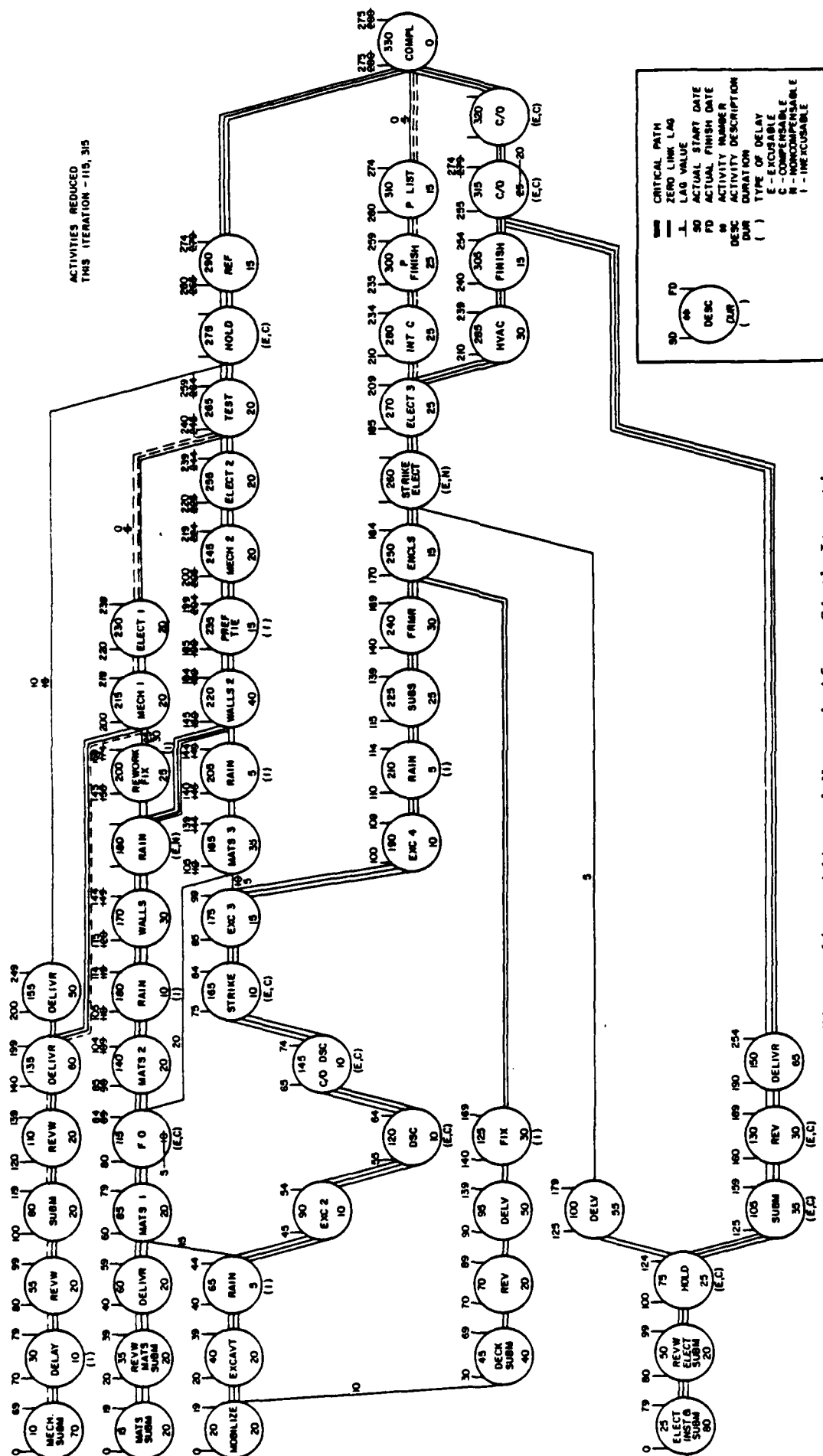
created: a long path (10-30-55-80-110-135-215-230-265-290-330) and a short path branching off the middle critical path (...-270-280-300-310-330).

Figure 14 shows that when the network is reduced to 275 days, five critical paths are created. Five days of excusable, compensable (change-order) delays have been removed in this iteration.

Seventh Iteration. In Figure 14, the critical path 10-30-55-80-110-135-215-230-265-275-290-330 contains only inexcusable delays, whereas the lower critical paths contain excusable delays. Further reductions in the project duration will necessitate the simultaneous reduction of inexcusable and excusable, compensable delays.

Theories related to concurrent delays have to be applied to determine the net effect of the next reduction. Concurrent reduction of inexcusable and excusable delays will produce a net nonexcusable delay.

To reduce the network duration, the inexcusable delay, mechanical submittal delay activity (30), must be deducted along with the field order activity (115), the DSC activity (120), and the instrument hold activity (75). The minimum duration among these activities is the five days associated with activity 115. Since no network logic restraints exist, the full reduction can be applied. The result is shown in Figure 15. The five-day network reduction results in the elimination of activity 115. The link lag value for 20-45 is reduced to five days. The concurrent reduction results



**Figure 14. Adjusted Network After Sixth Iteration**

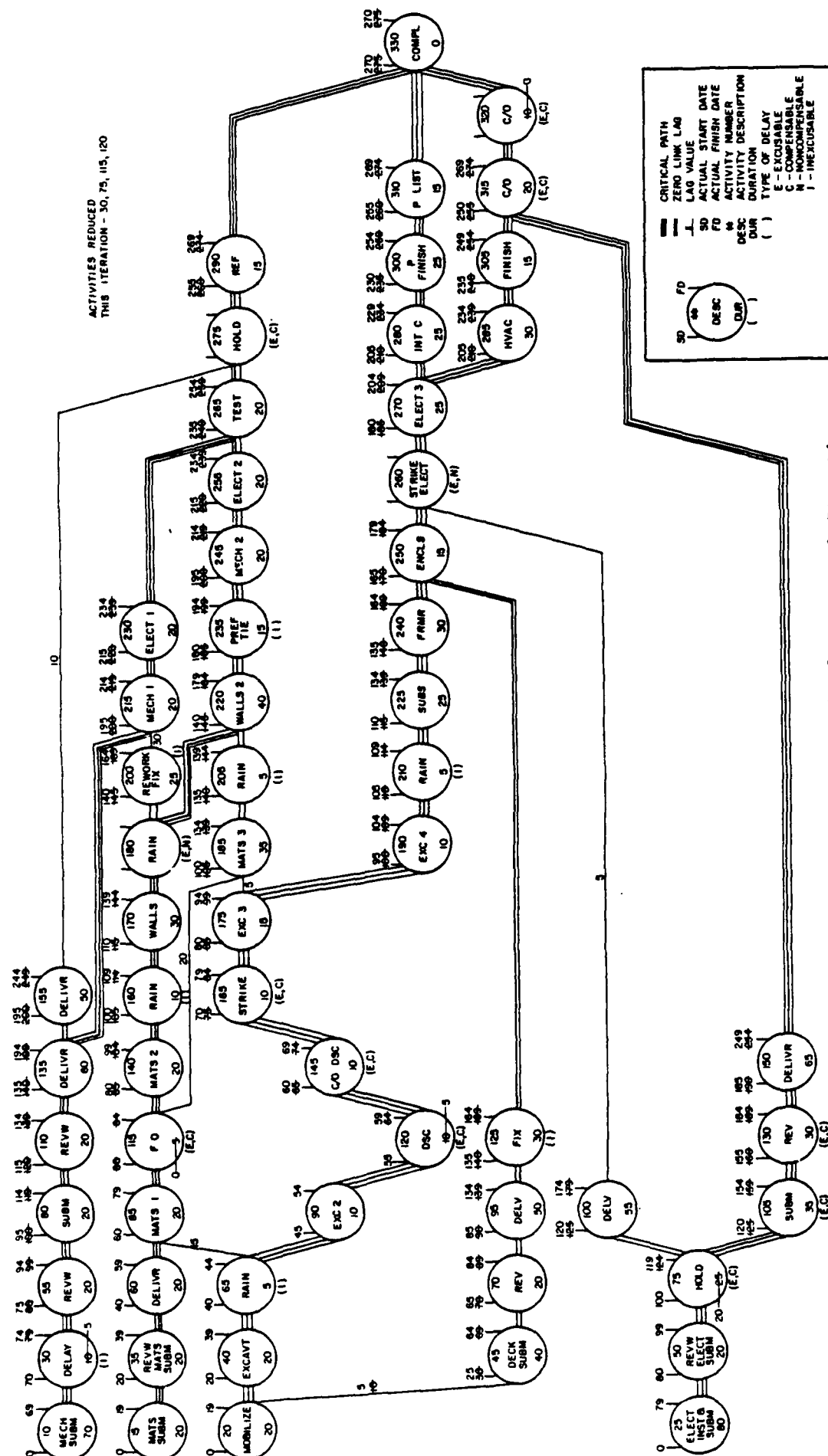


Figure 15. Adjusted Network After Seventh Iteration

in five days of nonexcusable delay removal from the network. The schedule now shows a project duration of 270 days.

Eighth Iteration. This adjustment cycle must also combine the reductions of inexcusable and excusable, compensable delays. Again, the theories pertaining to concurrent delay removal must be applied. Activities 30, 75, 120, and 235 are chosen to be reduced. The maximum reduction possible is five days, as established by activities 30 and 120. No logic restraints affect this reduction.

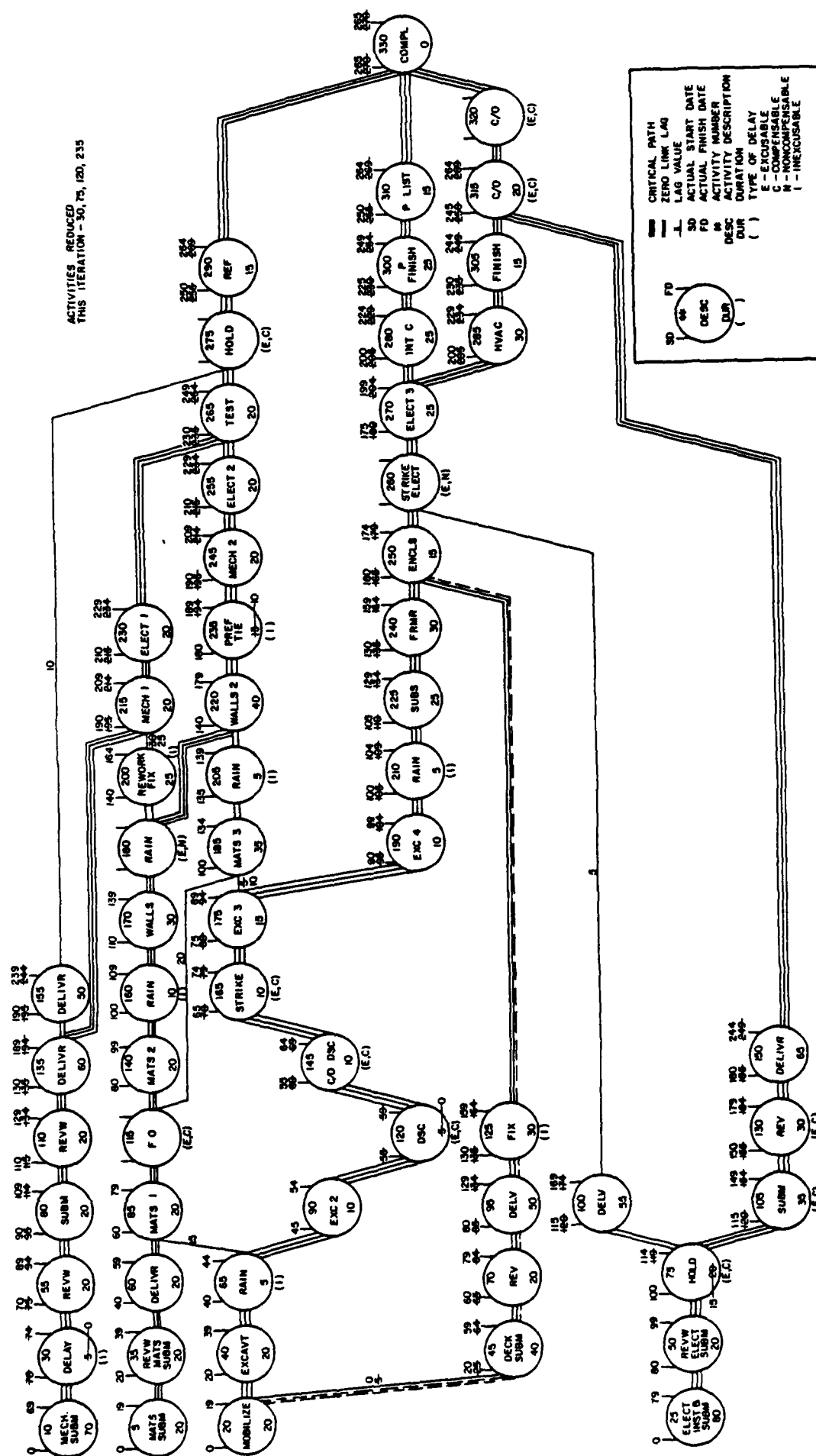
Figure 16 shows the new schedule. The concurrent removal of five days of inexcusable delay with five days of excusable, compensable delay produces a net five days of nonexcusable delay removed from the network.

Since the removal of activity 30 produces a critical path with no further documented delays, the reduction process is complete. The duration of 265 days represents the shortest possible time in which the contractor could have completed the work had there been no delay impacts. Figure 17 shows the final adjusted network.

#### Measurement of Delay Reduction

Once the final adjusted network has been obtained, an assessment of the delays removed from the schedule can be made. The number of days each categorical delay contributed to extending the project duration is totalled. Recovery for damages can then be based upon the extent to which each





**Figure 16. Adjusted Network After Eighth Iteration**

**Figure 17. Final Adjusted Network**

delay category contributed to extending the project's duration.

Table 2 lists delay(s) removed during each iteration. The type of delay resulting from the reduction of concurrent delays is shown in the "Effective Category" column of the table.

Table 3 summarizes the number of days of delay attributed to each category, which yields the following recovery for delay damages:

1. The contractor should be granted a 25-day time extension for excusable, noncompensable reasons
2. The contractor should be granted a 30-day time extension for excusable, compensable reasons
3. The contractor is entitled to extended delay damages for 30 days of compensable delays; however, the 15-day delay due to suspensions must exclude profit on the computation of the extended delay cost [14]
4. The contractor should be assessed for 25 days of liquidated damages

The actual adjustment process is straightforward. However, the theories pertaining to concurrent delays may not be operative, depending upon contract language.

#### Impact of Delay Selection Priorities

This section will demonstrate how the measurement of delay outcomes is affected by the order of priority used for

Table 2.  
Summary of Delays Reduced

Iteration	Activity Number(s)	Net Days Reduced	Type of Delay(s)	Effective Category
1	260	10	E,N	E,N
2	180,260	5	E,N	E,N
3	120,275	10	E,C (Suspension - Susp)	E,C (Susp)
4	120,275	5	E,C (Susp)	E,C (Susp)
5	115,320	10	E,C (Change Order - C/O)	E,C (C/O)
6	115,315	5	E,C (C/O)	E,C (C/O)
7	30,75,115,120	5	I + E,C(C/O) + E,C(Susp)	E,N ‡
8	30,75,120,235	5	I + E,C(Susp)	E,N ‡

---  
55 days of reduction

‡ - Based on theories of concurrent delays from reference [12]

Table 3.  
Summary of Delays Removed, by Category

Total Days Reduced	Type of Delay
25	E,N - Excusable, Noncompensable
15	E,C (Susp) - Excusable, Compensable Due to Suspension of Work
15	E,C (C/O) - Excusable, Compensable Due to Change Order Work

Actual Duration of Project 320  
 Excusable, Noncompensable Days Reduced - 25  
 Excusable, Compensable (Susp) Days Reduced - 15  
 Excusable, Compensable (C/O) Days Reduced - 15  
 Original Days Planned for Contract Completion - 240

----

Number of Days Chargeable for Liquidated Damages 25

choosing the activity to be reduced. This is accomplished by using a different order of priority for selecting delays for reduction on the sample as-built network. Excusable delays were chosen for reduction based upon their position in the network. Delays that occurred at the latest point in the critical path were given priority for reduction. The only deviation was when reduction of one excusable delay activity would produce reductions in multiple critical paths. This activity would have priority over a delay that occurred later. Table 4 lists the measurement of delay outcomes for the sample project using these selection criteria. The results are significantly different from those obtained in Table 2. Table 5 should be compared with Table 3 to see the difference between the delay categories for the two orders of priorities used. Table 3 indicated 15 days of compensable delays for both suspension of work and change orders. However, Table 5 indicates 30 days of compensation for change-order delays but no compensation for suspension-of-work delays. If the contract called for different compensation depending upon the type of excusable, compensable delay, the amount paid to the contractor could be substantially different. Depending upon the order of priorities used for delay selection, the resulting measurement of delay can favor either the owner or contractor.

Table 4.  
Summary of Delays Reduced Using Different Removal Logic\*

Iteration	Activity Number(s)	Net Days Reduced	Type of Delays	Effective Category
1	320	10	E,C (C/O)	E,C (C/O)
2	275,315	5	E,C (Susp) + E,C (C/O)	E,C (C/O) **
3	260,275	10	E,N + E,C (Susp)	E,N **
4	180,260	5	E,N	E,N
5	115,165	10	E,C (Susp) + E,C (C/O)	E,C (C/O) **
6	115,130,145	5	E,C (C/O)	E,C (C/O)
7	30,75,115,145	5	I + E,C (Susp) + E,C (C/O)	E,N **
8	30,75,115,145	5	I + E,C (Susp)	E,N **

---  
55 days of reduction

\* - Removal logic employed was to reduce latest occurring excusable delay and/or a delay that would reduce more than one critical path

\*\* - Based on theories of concurrent delays from reference [12]

Table 5.  
Summary of Delays Removed Using Different Removal Logic

Total Days Reduced	Type of Delay
25	E,N - Excusable, Noncompensable
0	E,C - Excusable, Compensable Due to Suspension of Work
30	E,C - Excusable, Compensable Due to Change Order Work

### Summary

This chapter has presented the methodology for adjusting an as-built schedule. Additionally, the process for allocating the delays removed during the adjustment was shown.

The methodology for adjusting the network is an iterative process. Specific steps are performed in each iteration to obtain a reduction in the project duration. The adjustment to the as-built network is completed once all delays have been removed from at least one of the critical paths. Delays removed during the reduction process are separated by categories and totalled. Recovery for damages can then be determined based upon the extent to which each delay category contributed to extending the project's duration. Theories of concurrent delays and the order of priority used for selecting delays to be removed can affect the outcome of the process.

## Chapter IV

### EVALUATING ACCELERATION

#### Introduction

The preceding chapter detailed the methodology for adjusting an as-built network for the purpose of analyzing a delay claim. Claims for acceleration costs are also common in the construction industry. Evaluating this type of claim often presents more difficulties than simply considering the delay issue by itself. This chapter will present a procedure that uses the adjusted network for evaluating responsibility for acceleration costs.

#### Acceleration Claims

The cost of acceleration can be considerable. Increasing the size of the work force, overtime, and adding more equipment are the main ways that the contractor can shorten the project schedule. The increased costs can quickly erode the profit on the project. Contractors are not likely to take this step unless absolutely necessary, but have little choice when an owner orders them to accelerate. Delays that resulted in the project being behind schedule may be excusable. If the owner directs acceleration and excusable delays are present, then the owner may bear some of the extra costs. A contractor is most likely to seek recovery for acceleration if he/she believes that delay was caused by the owner.



### Constructive Acceleration

A more problematic situation arises when an owner does not explicitly order acceleration but requests the contractor to get the job back on schedule. This situation is known as "constructive acceleration." In other words, the owner is insisting that the job be completed by the date specified in the contract (or a different date), but does not produce a written order to accelerate. The contractor may then seek to recover acceleration costs. In most cases, the contractor has to pay the costs. If the contractor feels that all or some of the delays were caused by the owner, then he/she can invoke the disputes procedure to recover those costs [7].

### Evaluation

The methodology presented in the previous chapter evaluated actual delays where there was no construction activity. Construction activities that take longer to complete than planned are not considered delays. The implication is that work has been performed in an inefficient manner. The contractor is normally charged for this inefficient work in the form of liquidated damages. A more complicated situation arises when constructive or expressly directed acceleration of the project schedule has occurred. Evaluating the responsibility for acceleration costs can be difficult at best. Many factors may affect the distribution of the increased costs. Projects rarely have delays that are caused solely by one party.

If delays were caused by the owner, then compensation to the contractor for acceleration costs may be justified. The owner-caused delays must be evaluated to determine if their impact made the acceleration necessary.

Acceleration resulting from inexcusable delays or inefficient work remains the contractor's problem. When directed to accelerate (constructively or expressly), the contractor bears the responsibility for accelerating the activities that will result in a shortened completion date. He/she is not entitled to recovery for accelerated activities that do not contribute to reducing the project duration. The contractor must carefully analyze what activities really need to be accelerated.

#### Acceleration Analysis Procedure

A procedure for determining the extent of owner liability for acceleration costs will be presented in this section. The adjusted as-built network will be used to measure how effective the acceleration was in shortening the project duration. Additionally, analysis of the adjusted network will identify excusable delays that contributed, in part, to the need to accelerate. With this information, an allocation of responsibility for acceleration costs can be made.

#### Adjusted Network

The final adjusted network reflects the shortest time in which the contractor could have completed the project,

excluding delays that directly extended it. Acceleration analysis using the adjusted network does not require further adjustment of the network. The adjusted network merely highlights the impact of accelerated activities upon the project completion date. This procedure is performed after the delay adjustment process. It is not performed in conjunction with the delay analysis.

The objective of this methodology, developed by the author, is to establish the owner's liability for constructive or expressly directed acceleration. No methodologies based upon this objective were found to exist while performing the literature research for this report. This procedure represents one, not necessarily the best, way to allocate acceleration costs.

#### Acceleration Analysis Steps

The steps to determine the extent of owner liability are listed below.

1. Determine the date of the acceleration order  
(direct or constructive)
2. Determine which activities were accelerated after the order
3. Calculate and show the difference in workdays between the planned and actual durations for each accelerated activity under its respective node
4. Total the days of acceleration for each critical path
5. Analyze all the paths containing excusable delays

to determine the extent of owner liability

6. List each accelerated path for which the owner is accountable and the net compensable days.

Step 1: Determine the date of the acceleration order: (direct or constructive). This step requires the determination of when the contractor received notification, direct or constructive, to accelerate. This information will most likely be obtained from the project records and correspondence. The acceleration order date is important because it establishes the point in time after which any accelerated activities can be considered for owner liability.

Step 2: Determine which activities were accelerated after the order. The project records and correspondence are researched to establish which activities were actually accelerated after the order date.

Step 3: Calculate and show the difference in workdays between the planned and actual duration for each accelerated activity under its respective node on the adjusted network. This difference is the number of days each activity was accelerated. It is important to note that all accelerated activities which lie on the adjusted network critical path(s) have an impact upon project duration. Additionally, accelerated activities on a chain that leads into a critical path may also have had an impact upon the completion date and must be considered in the analysis.

Step 4: Total the days of acceleration for each critical path. This highlights the effect of the acceleration. This step requires adding the days accelerated for each activity on each critical path. The path with the maximum acceleration indicates the number of days the project would have finished beyond the adjusted completion date (the number of days for which liquidated damages could have been imposed had the contractor not accelerated).

Step 5: Analyze all the paths containing excusable delays to determine the extent of owner liability. This step is the most difficult because it requires careful analysis of the adjusted network. The objective is to determine which critical path(s) had to be accelerated because of excusable delays. If the delay in the critical path is excusable, then the owner is responsible for the acceleration costs. Accelerated paths in the network that contain only inexcusable delays or no delays cannot be laid to the owner's account. The contractor is responsible for these costs. Where inexcusable and excusable delays occur on the same path, the difference between the two types of delays is calculated to give a net excusable or inexcusable delay.

The total number of acceleration days attributed to the owner for a path cannot be greater than the total duration of excusable delays in that path. For example, if a path

reflects a ten-day excusable delay and 15 days of accelerated work, then the owner is only responsible for ten days of acceleration costs.

Step 6: List each accelerated path for which the owner is accountable and the net compensable days. Once all of the accelerated paths have been evaluated to determine if excusable delays had a net effect upon delaying the path, the extent of the owner's liability will be known. The owner would be responsible for the net amount of days that the excusable delay(s) contributed to accelerating a path. The contractor would be responsible for all the remaining acceleration costs.

#### Example of Acceleration Analysis

The adjusted as-built network developed in Chapter III will be used to give an example of the acceleration analysis procedure discussed above. This adjusted network reflects the shortest possible time in which the contractor could have completed the work in the absence of delays.

##### Step 1

Assume that on day 190 the contractor received notification to accelerate from the owner. The order could have either been direct or constructive. In an actual situation this point in time would be obtained from analysis of project records.

### Step 2

Using the project records, the activities accelerated after this date are determined. The adjusted schedule in Figure 17 is used for this analysis. Activities in progress at day 190 can be considered for acceleration if the project records indicate that they were indeed accelerated. Let it be assumed the activities 150 and 270, although in progress at day 190, were accelerated. All of the other activities starting on day 190 or later were also identified as accelerated activities from the project records.

### Step 3

The number of days each activity was accelerated was calculated by noting the difference between the planned and actual durations. Each activity that was accelerated is annotated by placing the capital letter "A" and the number of days of acceleration under its respective node, as shown in Figure 18.

### Step 4

The acceleration in each critical path is totalled. Table 6 reflects the total acceleration values for each critical path.

**Figure 18. Final Adjusted Network Reflecting Accelerated Activities**



Table 6.  
Total Path Acceleration Values

	Critical Path	Total Acceleration
10 ...	215-230-265-290-330	17 days
15 ...	245-255-265-290-330	17 days
20 ...	270-280-300-310-330	14 days
20 ...	270-285-305-315-330	14 days
25 ...	150-315-330	15 days

Figure 19 is a time scale drawing of the portion of the network that was accelerated. The diagram reflects the impact of acceleration upon each activity. Figure 20 displays a time scale representation of how the schedule would have looked had the project not been accelerated. By referring to Table 6 and Figure 20, it can be seen that the maximum acceleration to a particular critical path is 17 days. If the contractor had not accelerated, the project would have finished 17 days beyond the actual completion date.

Comparison of the cost for 17 days of liquidated damages versus the cost of 17 days of acceleration to the schedule could prove beneficial in future projects. The contractor wouldn't be entitled to compensation for acceleration unless excusable delays contributed to the 17 day overrun.

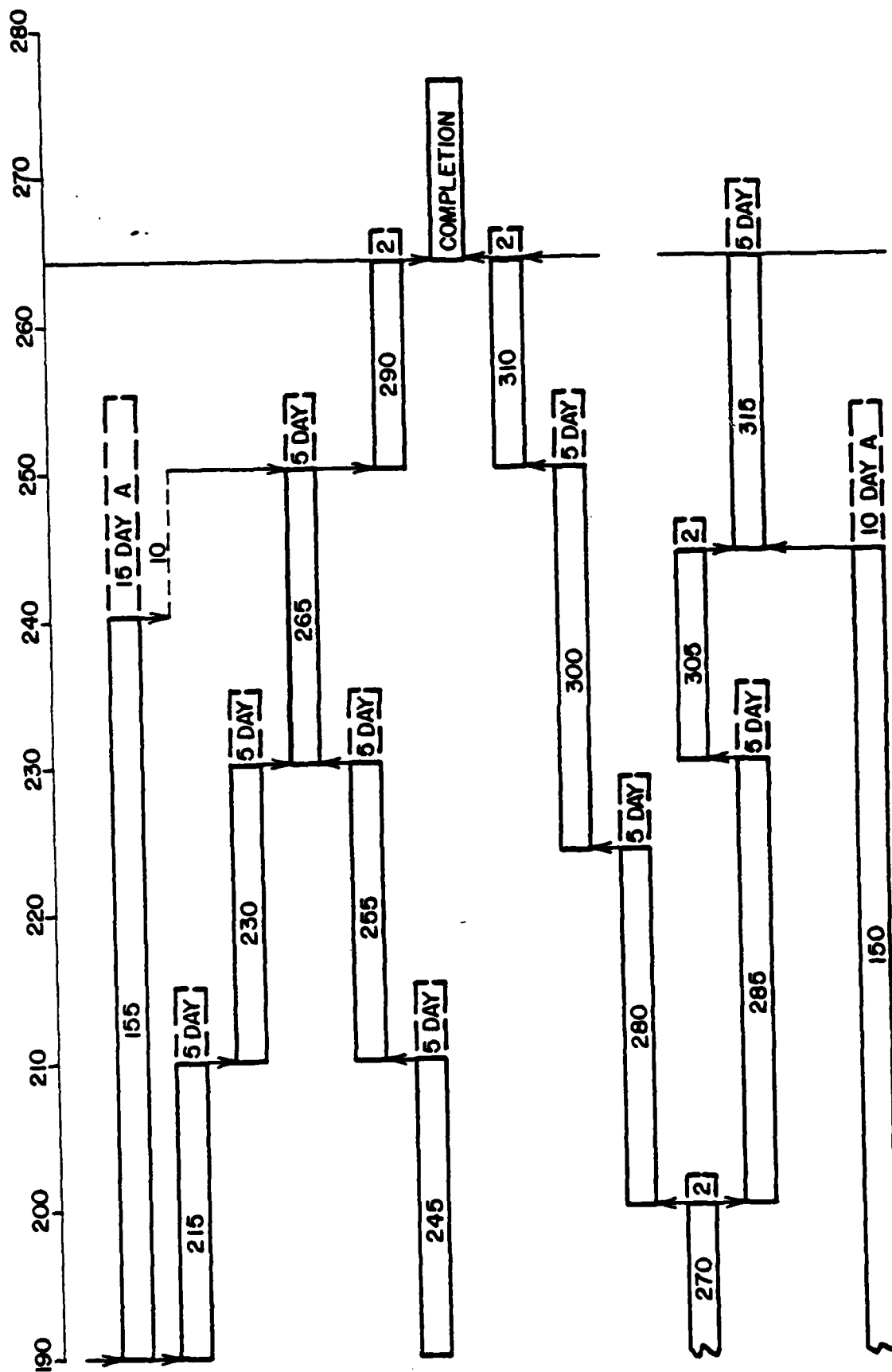


Figure 19. Time Scale Network Reflecting Acceleration Effect for Each Activity

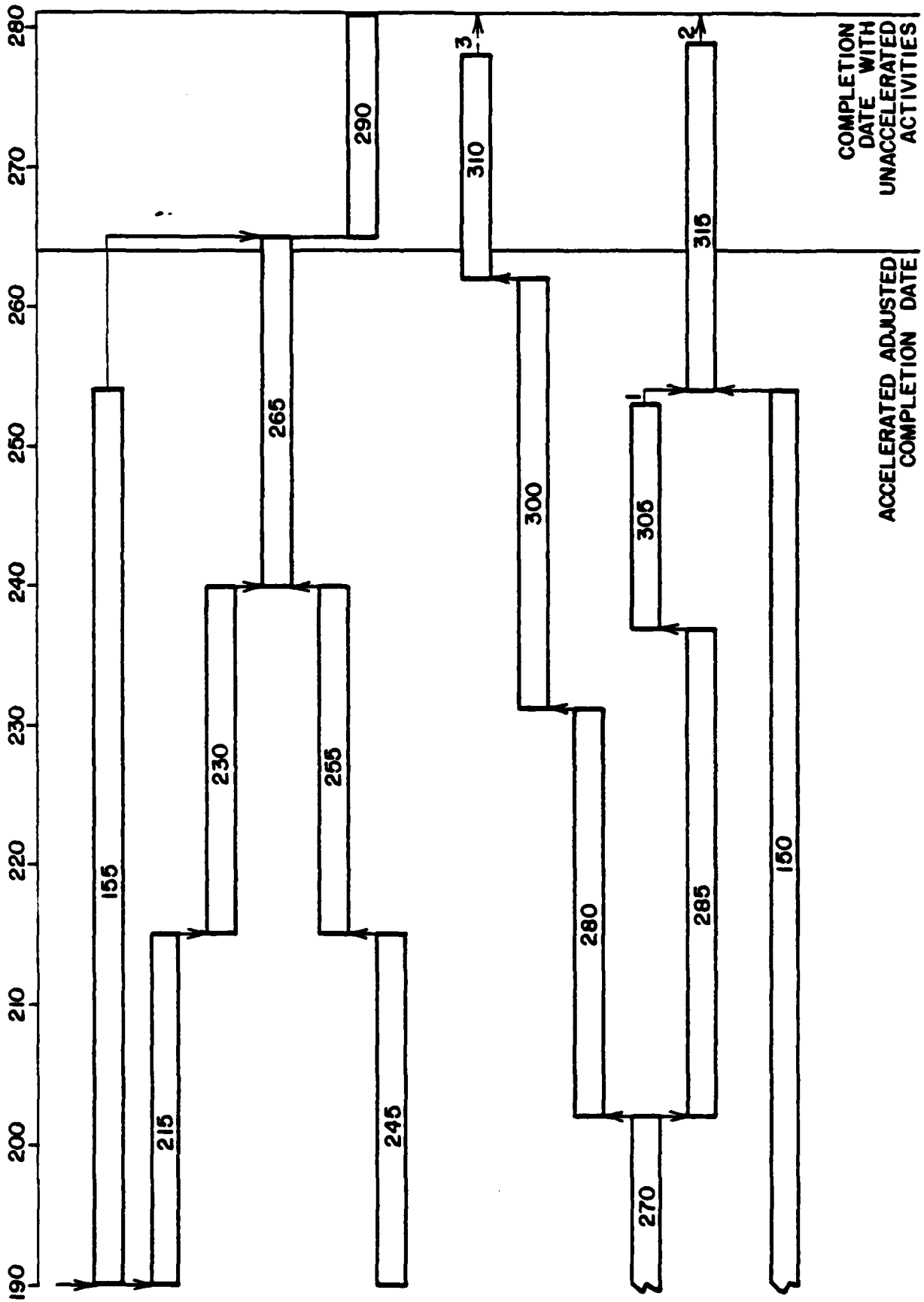


Figure 20. Time Scale Network Reflecting Unaccelerated Activity Condition

### Step 5

Actual identification of which accelerated paths were affected by excusable delays is accomplished in this step. Referring to Figure 18, each path is evaluated to see if excusable delays are present. Starting with the uppermost critical path (10...215-230-265-290-330), it is seen that no delays are evident on this path. The contractor would be responsible for all acceleration costs for activities on this path. The next critical path (20...235-245-255-265-290-330) shows no excusable delays. Again, the contractor would be responsible for all acceleration costs associated with this path. Proceeding downward, the next two critical paths merge at node 250 before any accelerated activities occur. Therefore, the two paths must be evaluated together to determine the net effect of the excusable and inexcusable delays. The upper critical chain (20-40-...-250) contains two excusable delays totalling 20 days, and contains ten days of inexcusable weather delays. The lower critical chain (20-45-...-250) reflects 30 days of inexcusable delays. The total days of inexcusable delays ( $30 + 10$ ) is subtracted from the 20 days of excusable delays. This results in a net effect of 20 days of inexcusable delays to the critical path prior to the path branching at node 270. Each branching critical path must be analyzed independently to determine the net delay for that path. Analyzing the critical path that branches at node 270 (270-280-300-310-330) it is seen that no additional delays are present. The

contractor could not expect compensation since there are no further excusable delays to alter the 20 days of net inexcusable delay accrued in the early portion of the path. The other path (270-285-305-315-330) contains an excusable delay of 25 days, activity 315. The net effect is now 25 days of excusable delays minus 20 days of inexcusable delays. Thus, the owner is responsible for five days of acceleration costs to this critical chain. Finally, the critical path at the bottom of the network (25-...-150-315-330) is evaluated. This path reflects a total of 120 days of excusable delay. The owner is responsible for the total cost of acceleration to this path.

#### Step 6

Now that the extent of owner liability for acceleration has been determined, the two parties can negotiate the amount of compensation. In summary, the owner should compensate for five days of acceleration to the chain 270-285-305-315 and 15 days of acceleration to the chain 75-105-130-150-315-330.

#### Summary

This chapter detailed a procedure for evaluating an acceleration claim. The use of the adjusted network to identify the net effects of the accelerated schedule was presented. Steps to serve as a guide for evaluating acceleration were also detailed. This methodology can assist in identifying the owner-caused delays that

contribute to the need for acceleration. Once the extent of owner liability has been identified, the two parties can negotiate the proper amount of compensation.

## Chapter V

### CONCLUSIONS AND RECOMMENDATIONS

This report has presented a methodology for adjusting an as-built network to evaluate the cause-effect relationship of delays. The preliminary steps for establishing an accurate as-built network were detailed prior to presenting the adjustment methodology. The steps in the adjustment process were then described. Next, an example was given to assist in understanding the adjustment technique. The assessment of delays using the sample project was then shown. A process for evaluating acceleration claims using the adjusted network was presented. A sample project was used to clarify the steps.

#### Conclusions

The large number of delay claims in today's construction industry necessitates a method for settling these disputes. The situation is complicated by the frequent lack of documentation and the inability to assess the cause-effect relationship of delays. Reliable and accurate analysis of a claim requires a thorough knowledge of the contract documents and project records. The networks that are used in claim presentations must accurately portray the sequence of events and must be corroborated by the project records. An inaccurate schedule has a serious impact upon the validity of a delay analysis. The value of

CPM networks for claim analysis purposes is recognized by many experts and accepted in courts.

An adjusted as-built network can be a valuable tool for delay analysis. By highlighting the delays that actually affected the project completion, it allows compensation and damages to be assessed in a logical manner. The adjustment process requires an in-depth analysis of the network. The number of days of delay attributed to each category for extending the project duration is dependent upon the order of priority used for removing delays. Thus, the order of priority affects the allocation of responsibility for extending the project's duration.

A final adjusted network can also be used to assist in the analysis of acceleration claims. Project documentation is used to determine when the acceleration order was effected and what activities the contractor accelerated. The acceleration's effect upon project duration is then highlighted with the adjusted network. Excusable delays that necessitated acceleration of critical paths can be determined by analyzing the adjusted network. This establishes a basis for the contractor and owner to negotiate appropriate compensation.

#### Recommendations for Future Research

This report details two methodologies: one for adjusting a network to allocate delay responsibility and the other for using the adjusted network for evaluation of



acceleration claims. Further research is needed to develop a rationale for selecting the delays to remove during the adjustment process. This removal logic should favor neither the owner nor the contractor. Additional studies to adapt the adjustment process into a computer program could be highly beneficial to the industry. A program could significantly decrease the amount of time needed for network analysis, particularly in identifying restraints in the network and performing reduction calculations. Finally, the methodology for analyzing acceleration needs to be verified and tested on an actual construction project.

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